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Anyanwu, Ruth; Nisar, Fawwad; Rodriguez, Cristina; Durrant, Andrew; Olabi, Abdul-Ghani

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# SUSTAINABLE DEWATERING OF MICROALGAE BY CENTRIFUGATION USING IMAGE 4-FOCUS AND MATLAB EDGE DETECTION

R.C. Anyanwu, F. Nisar, C. Rodriguez, A. Durrant, A.G. Olabi  
Institute of Energy and Engineering Technologies, University of the West of Scotland,  
Paisley PA1 2BE United Kingdom  
Ruth.Anyanwu@uws.ac.uk

## ABSTRACT

In this study, we demonstrate the feasibility of centrifugation for the successful dewatering of microalgae species. Centrifuge experiments were conducted on *Scenedesmus quadricauda* and *Chlorella vulgaris* at different centrifugal speeds between 1000-4000 (rpm) and varying time between 5-30 (min). Dewatering efficiency and microalgae cell disruption were evaluated. Image-focus 4 and Matlab edge detection software were used to model the effect of centrifugation on microalgae cell walls and to determine the water removal ratio. Experimental results indicated that centrifugation technique is an effective approach for dewatering microalgae under specific conditions. *Scenedesmus quadricauda* showed a maximum dewatering efficiency of 82% and *Chlorella vulgaris* of 91%. Centrifugation under 4000 rpm at 10 minutes did not show any significant cell damage on the algae cell structure for both species. This study provides information on specific impact of centrifugation on *Scenedesmus quadricauda* and *Chlorella vulgaris* for the first time, which is, centrifugation technique under specific conditions (4000 rpm for 10 min) is a successful method for dewatering microalgae without damage to the cell wall. This study therefore provides sustainable option for microalgae dewatering technique in the energy industry.

**Keywords:** Microalgae, Centrifugation speed, Dewatering, Matlab edge detection.

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Corresponding author: Ruth.Anyanwu@uws.ac.uk

## 1 INTRODUCTION

Microalgae are unicellular organisms with complex and robust cell walls. They have been appraised as biological solar panels as they have the capability to fix CO<sub>2</sub> efficiently from different sources, including atmosphere, industrial exhaust, and gases. They also have the ability to produce intracellular storage compounds mainly protein (50-60%), [1]carbohydrates (10-20%) [2], and lipids (20-30%) [3]. Microalgal lipids (20-40%) consist mainly of esterified glycerol saturated and unsaturated fatty acids with a chain length of primary C<sub>16</sub> and C<sub>18</sub> fatty acids, when processed are important in the production of products such as biodiesel [4], bioethanol, pyrolysis oil, bio-synthetic gas (syngas), refuse-derived fuel (RDF), biogas, biomethane [5], hydrogen technologies [6] and other advanced biofuels. Interestingly, end uses are in transport, electricity, heat [7] and contribute positively to the future of renewable energy [5], [8]. These contributes to a sustainable quality of life which is well reported as the basic driver for providing a clean, safe, reliable and secure energy supplies around the globe [6]. The combination of CO<sub>2</sub> fixation, biofuel production, wastewater treatment, as well as the production of high value end products such as human and animal and feed, pharmaceuticals

and cosmetics makes microalgae a very promising material for use in industrial processes [9], [10], [11]. Common microalgae harvesting and dewatering operations are accomplished through centrifugation [12] freeze drying [13], bioflocculation[14], flotation, flocculation, sedimentation [15], filtration [16], or combination of above methods. Currently there is no superior or universal method suited to all algae species for dewatering purposes. Major drawbacks are high capital cost, high energy consumption, risk of contamination, cell damage and time consumption, the suitability of each process depends on the properties of the microalgae specie, the required process design, the quality of the end product, and the related capital and production costs [17], [18].

Among these process, centrifugation is the most efficient method (over 95% algae biomass could be obtained) and is widely used for microalgae cells harvesting in lab-scale or pilot-scale microalgae cultivation systems. However, the cell damage by this technique impede its further application at a large scale [19], [20]. A careful review of the available literatures revealed that in spite of centrifugation study and the conclusion generally reported that this technique damage microalgae cell wall, none of these literatures assessed the level of damage on microalgal cell for centrifugation technique. Thus, in the present study, the effect of centrifugation on fresh water microalgae *Scenedesmus quadricauda* and *Chlorella vulgaris* is investigated to assess the level of cell damage and optimize the operational conditions for an increase dewatering efficiency.

## 2 MATERIALS AND METHODS

### 2.1 Microalgae strain and medium

*Scenedesmus quadricauda* and *Chlorella vulgaris* (UTEX 2714 and 1589) were obtained from University of Texas at Austin. The algae were cultivated in a closed photobioreactor (PBR UTEX) (Fig 1) and sterilized BG 11 medium with the following composition NaNO<sub>3</sub>Mm; K<sub>2</sub>HPO<sub>4</sub> 0.23Mm; MgSO<sub>4</sub>.7H<sub>2</sub>O 0.3Mm; CaCl<sub>2</sub>.H<sub>2</sub>O 0.24MmNa<sub>2</sub>EDTA.2H<sub>2</sub>O 0.0027Mm; Na<sub>2</sub>CO<sub>3</sub> 0.19Mm.



Fig 1. Closed PBR.

### 2.2 Centrifugation experimental design

Experiments were conducted at varying rotational speeds (RPM) and time (min) to investigate dewatering efficiency. Dewatering efficiency was calculated by Equation (1)

$$DE(\%) = \frac{\omega_1 - \omega_2}{\omega_1} \times 100 \quad (1)$$

where  $\omega_1$  is the moisture content of the sample before drying and  $\omega_2$  is the moisture content of the sample after drying. In centrifugation, it is important to differentiate between the speed of

centrifugation rotations per minute (RPM) and the relative centrifugal force (RCF or G) since these are often confused [21]. The centrifugation force is generated by a centrifuge can easily be calculated from the Equation 2

$$RCF = 11.18 \times R \times \left(\frac{RPM}{1000}\right)^2 \quad (2)$$

Where R is the radius of the rotor in centimetres that is, the centrifugal force increases as the particle move down the centrifuge tube. As a rule the greater the centrifugal the shorter the separation time. However, centrifugation generates hydrostatic forces within the solution and so excessive centrifugal forces can disrupt some biological particles [21]. Medium size centrifuge (Centaur 2 MSE PA3985) was used in this study. The centrifuge consists of four 50ml swinging bucket rotor; the distance from the centre of rotation is 7.5 cm (Fig.2).



Fig 2 Centrifuge.

### 2.3 Image processing

Cell images were acquired using Novex B-range microscope (Holland) images were captured using Euromex microscope at 40x camera with ImageFocus 4 software. The force exerted on the microalgae sample in the centrifuge during experimentation was calculated using Equation 3. This is important as this gives better understanding of the mathematical process of the lab scale with anticipation that this will help scaling up from lab to pilot or commercial scale. Further, it is essential to determine the G-force this is represented by Equation 3.

$$G. force = \frac{rw^2}{g} \quad (3)$$

Where r is the radius from the centre of the rotor in (cm), w is the number of revolution, g is the relative centrifugal force (RCF). The experimental parameters, rotation per minute (rpm) and time varies between 1000-4000 while time varies between 5-30 minutes respectively. All experiments were run at least in duplicate. The total weight of dried algae sample was calculated.

### 2.4 MATLAB Edge Detection

MATLAB edge detection was performed to optimize the centrifugation process and to quantify the water removal ratio, to distinguish the significance within each centrifugation time and rpm and interactions between these parameters and to determine the significance within each factor based on the centrifugation results. MATLAB R2016b was used as the main software for the purpose of graphical method of analysis.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Centrifugation effect on cell wall

Edges detection describes boundaries and is of fundamental importance when it comes to analysing data and images. Image Edge detection significantly reduces and filters out

unnecessary information, while preserving the vital structural properties in an image. Figure 3 shows the effect of varying centrifugation speed for *Scenedesmus quadricauda* and *Chlorella vulgaris*. The black and white images shown adjacent to each figure are after the edge detection, where the white part represents water and the black the cell wall. It was observed that centrifugation was effective in dewatering the algae culture. Further, the result shows that the cell walls are largely aligned within the sample surface area.

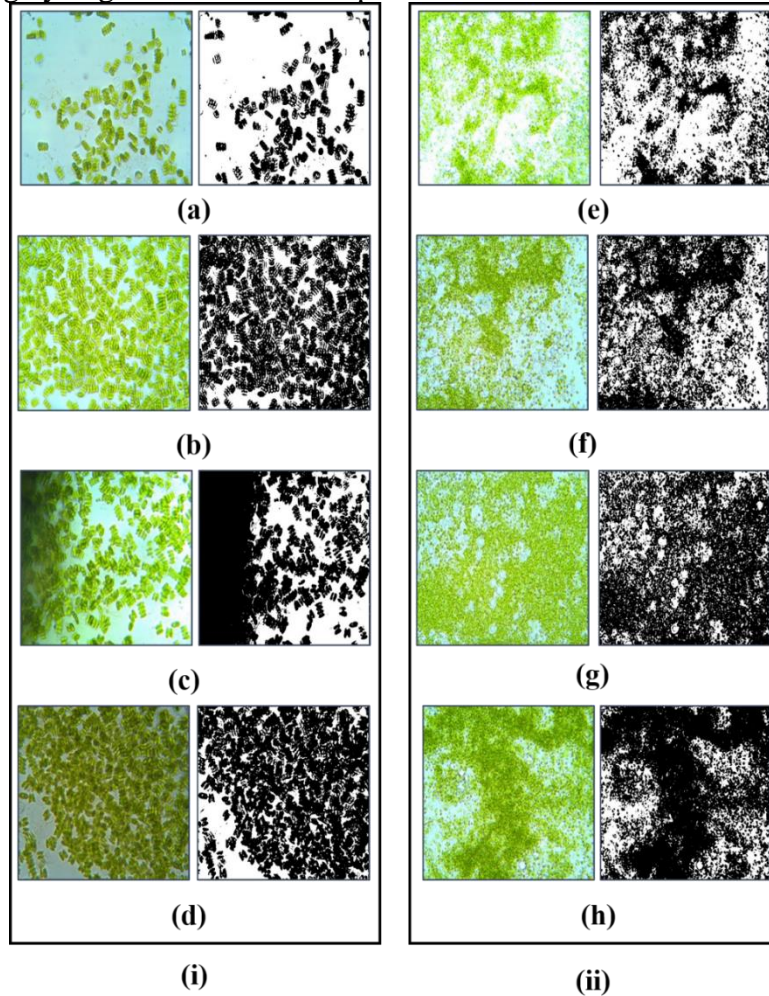


Figure 3. Image processing results for varying centrifugation speeds at constant time of 15 min (i) *Scenedesmus quadricauda* (a) 1000 RPM (b) 2000 RPM (c) 3000 RPM and (d) 4000 RPM, (ii) *Chlorella vulgaris* (e) 1000 RPM (f) 2000 RPM (g) 3000 RPM (h) 4000 RPM.

The Matlab data extracted from software illustrated in Fig 4 shows higher dewatering rate was obtained at higher RPM. Overall, water content decreases exponentially with increasing RPM. It was also observed that for centrifugal speed greater than 2500 RPM the water content removed remained constant. The biomass concentration increased greatly at 10min (Fig 5). Subsequently decreasing at increasing time, this is probably because the cell walls are affected significantly at increasing centrifugation time.

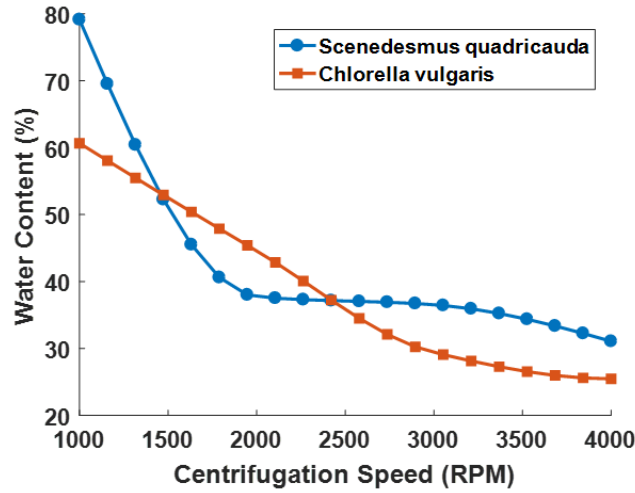


Figure 6. Data extraction of algae samples for varying centrifugation speeds between 1000 – 4000 RPM at constant time of 15 min using MATLAB Edge detection.

The experimental parameter time is observed to be more important, at 10 min as can be displayed (Fig 5), the biomass concentration of *Chlorella vulgaris* was found to be 17.6 g/L, similar pattern was reported by [22]. The minimum biomass concentration biomass concentration was at higher centrifugation time (30 min).

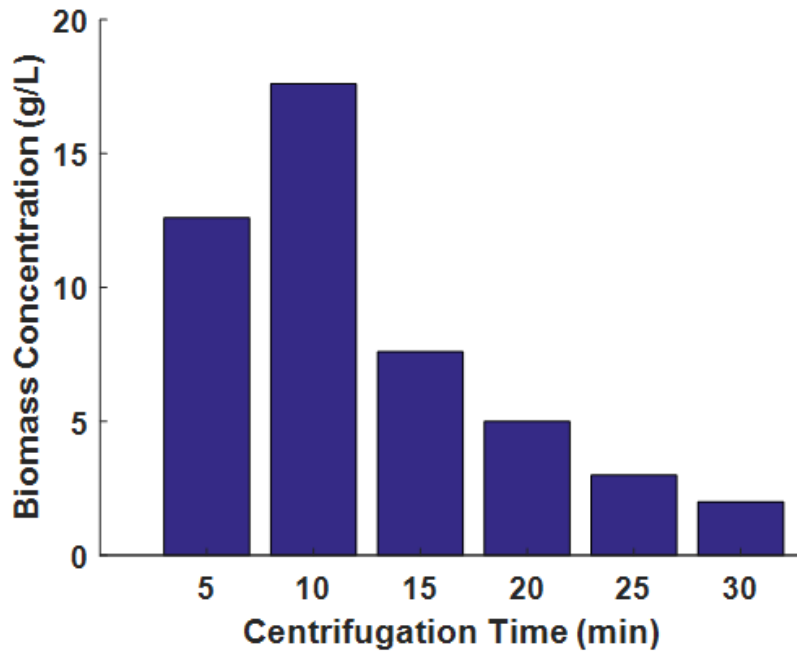


Figure 5. Biomass concentration v centrifugation time for *Chlorella vulgaris*

For centrifugation greater than 15 mins at 4000 RPM, the cell walls were damaged. Due to limitations with the edge detection method, the analysis was not performed on such samples. Figure 6 shows the images of control samples for centrifugation times greater than 15 mins where it can be seen that the cell walls are damaged. The cell walls for *Scenedesmus quadricauda* were greatly affected compared to *Chlorella vulgaris*.



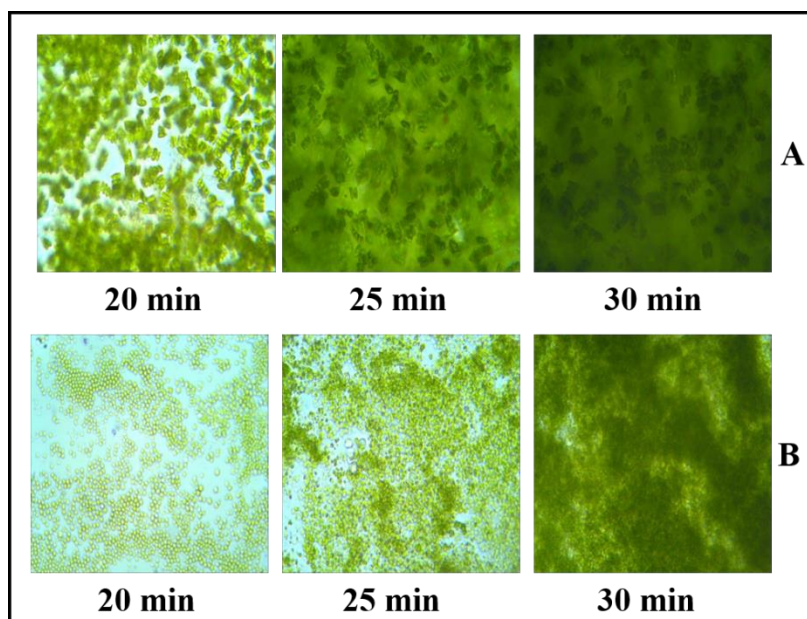


Figure 6 Cell wall damage at greater centrifugation times running at 4000 RPM for (A) *Scenedesmus quadricauda* (B) *Chlorella vulgaris*.

#### 4 CONCLUSIONS

Centrifugation technique was assessed for efficient dewatering *Scenedesmus quadricauda* and *Chlorella vulgaris*. Using centrifugation is fast, in all treatments at 4000 RPM for 10 minutes comparing with the control cells, there was no damage on microalgae cell walls. Centrifugation time is what probably weakens the cell walls since prolong time exposes cell to extreme shear stress. Hence, centrifugation could be used at short duration as cells were more resistant to hydrodynamics force during centrifugation at 5 and 10 mins respectively. Current results suggest that centrifuges may be applied in microalgae pretreatment upon design and operation to minimize negative consequences on microalgae quality. From these findings consequently we conclude that

- Centrifugation can be applied for microalgae dewatering. This process enables algae dewatering efficiency (up to 82% *Scenedesmus quadricauda* and 91% *Chlorella vulgaris* this study).
- The specific performance can be scaled up to commercial scale. some authors have reported that the greater the centrifugal the shorter the separation time [21], an optimum RCF value of 167.7 was obtained for 4000 RPM in this study.
- For biodiesel and lipid extractions centrifugation is recommended as this will rupture the microalgae cell wall since this is related to time taken to pre-treat algal biomass using conventional pretreatment method. Overall this will save time also translates to low energy usage.
- On the basis of the observation from these extensive experiments, it is greatly possible to centrifuge microalgae in practice depending on time and rotation speed. It is expected that this work will be useful for the cultivation and dewatering application of microalgal in the industries.

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